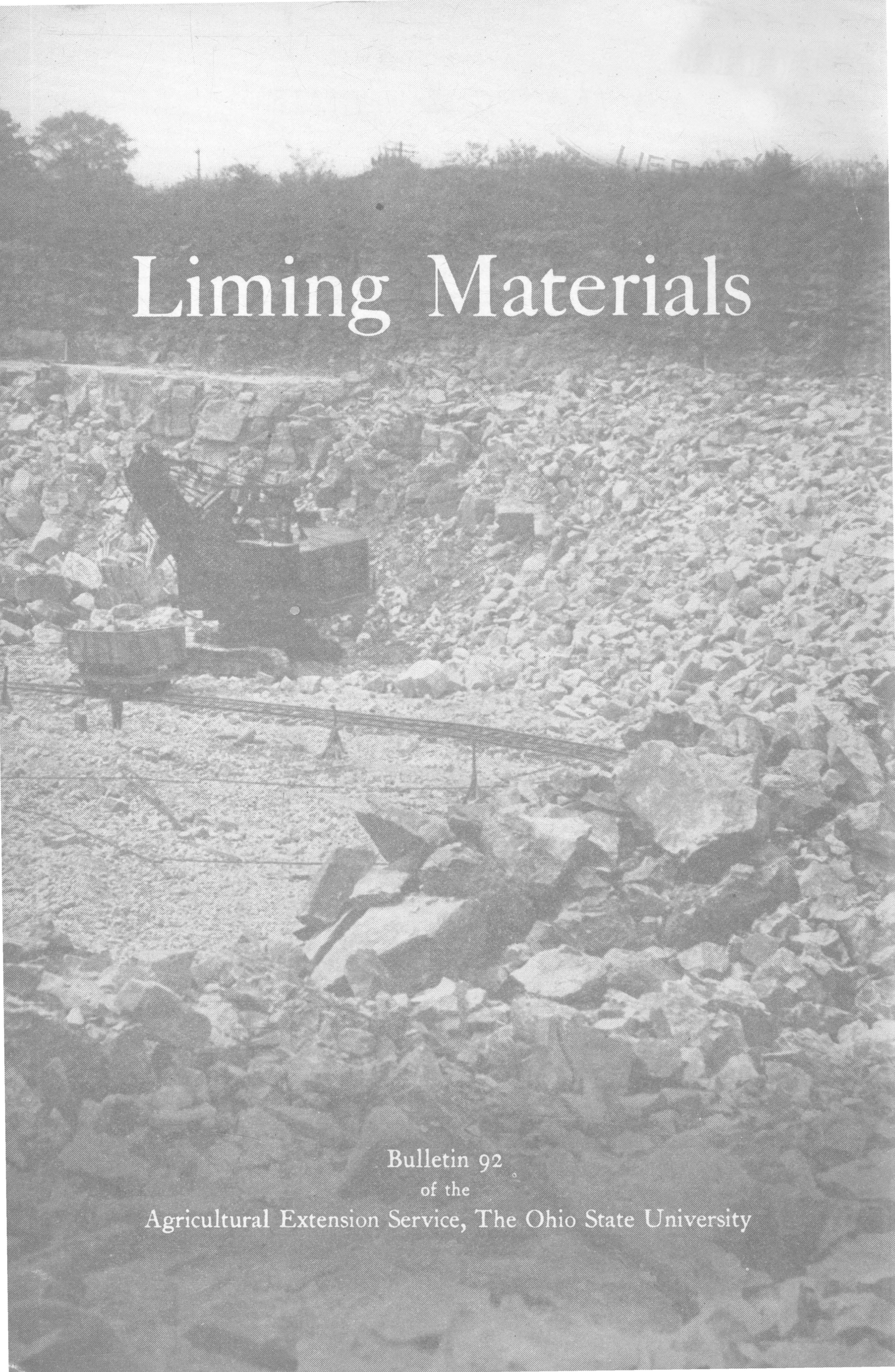

# Liming Materials

Bulletin 92
of the
Agricultural Extension Service, The Ohio State University

# LIMING MATERIALS

M. V. Bailey
Extension Specialist in Soils
The Ohio State University

THE history of agriculture definitely points to the fact that the need for lime in the soil becomes more acute a few years after the opening up of new land. As forest land is cleared and put under cultivation soil acidity develops because of the loss of lime. The leaching of lime in drainage water, the solvent action of the acids produced in the decay of organic matter, sulfur from the atmosphere, and removal of lime by crops all contribute to this continual loss. Soil acidity or "sour soil" is the direct result of these losses.

## OHIO SOILS SHOW VARYING DEGREES OF ACIDITY

The degree of acidity found in Ohio soils varies over a wide range. On many thousands of acres so much acidity has developed that profitable crop production is limited.

*Conditions in Eastern Ohio.*—The soils of eastern Ohio are largely of sandstone and shale origin with very small amounts of limestone appearing. Many soil tests in this part of the state show the predominance of acid soils. There are but few unlimed soils which are still alkaline.

In the northeastern part of the state all unlimed soils are acid, while in the central and southeastern parts there are small areas of limestone origin which are not yet acid. Except for these small limestone areas, and some of the river bottoms, all eastern Ohio soils need lime for alfalfa and sweet clover. Most of them need some lime for red clover. The amount needed per acre varies within wide limits.

The unlimed extremely heavy clay soils of northeastern Ohio are very acid. They also require heavier applications of lime to the acre to give a definite reduction in acidity than are required to produce an equal change on the lighter types of soil throughout eastern Ohio.

Most of the muck soils and other small areas of unproductive black soils in this part of Ohio are extremely acid; the *p*H value often being as low as 4.00 (see page 13).

*Conditions in Western Ohio.*—The soils of western Ohio are of glacial limestone origin and therefore are not strongly acid. The results of many soil tests in this territory indicate that about 30 per cent of the soils needs lime for alfalfa or sweet clover. Many of these soils are even alkaline.

The dark colored soils of this part of Ohio will usually produce alfalfa or sweet clover without liming, but most of the grayish-brown soils require some lime for these crops. The ashy-gray soils invariably need some lime, usually at the rate of 1½ tons per acre of agricultural ground limestone. Complete failures of red and alsike clovers in western Ohio are rare because of the lack of lime.

The soils in a comparatively small area in the extreme southwestern corner of Ohio are an exception to the foregoing. This area is often referred to as the "old glacial soils area" and comprises most of Clermont, Brown, and Hamilton Counties, and the

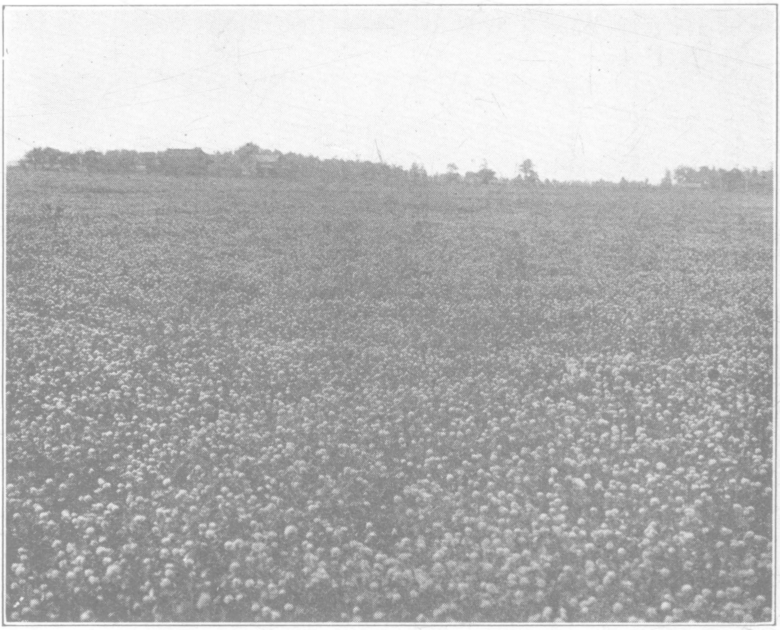

Fig. 1.—It takes limestone to grow clover like this.

southern half of Clinton, Highland and Warren Counties. The soils in this area are of glacial limestone origin, but were formed ages previous to the soils to the north. They have accordingly been subjected to much more leaching, with the result that they have become highly acid. Practically all require liming for red clover.

Throughout western Ohio, including the "old glacial soils area," occur brown terrace soils (second bottom) underlaid with gravel. Of these the silt loams and loams are in need of lime in three-fourths of the cases. The amount needed for alfalfa or sweet clover varies from 1 to 1½ tons per acre of agricultural ground limestone or its equivalent in hydrated lime. The sandy loams and gravelly loams are less frequently acid. About one-fourth of them need from ½ to 1 ton per acre of agricultural ground limestone to fit them for alfalfa or sweet clover.

### RATE OF LOSS OF LIME

Studies of the rate of loss of lime from soils indicate amounts ranging from 200 to 800 pounds of lime carbonate per acre in a year. The greatest loss of lime is through drainage water and crop removal. The following figures give perhaps the closest estimate available in Ohio. Based on river water analyses of the Miami river at Dayton and the Muskingum river at Zanesville and on the crops of the respective areas drained by these rivers, the loss of

Fig. 2.—Storing ground limestone in a pile in the field is sometimes recommended, but it is well to remember that if it becomes wet it can be spread only with more or less annoyance.

lime carbonate amounts to 585 pounds per acre a year for the Miami basin and 405 pounds for the Muskingum basin. It is to be expected that the loss would be more rapid in western Ohio because of the abundant supplies of natural lime in the soil. The foregoing figures indicate the loss of lime from the entire soil profile. The loss from the plow layer of soil would doubtless be somewhat less.

There is evidence that the Ohio farmer needs to apply a ton of limestone once in four to six years to replace the losses from his cultivated soil.

### PROBLEM OF CORRECTING SOIL ACIDITY

Acid or sour soils are most economically and satisfactorily neutralized by some form of lime applied for that specific purpose.

Certain fertilizers contain some lime, but the percentage contained is usually so low and the application on an acre so small that there is little hope of meeting the need for lime with such materials. This is particularly true of soils in which considerable acidity has already developed. On soils that are still neutral or slightly alkaline there may be opportunity to maintain the lime supply, or at least to delay for some time the need for large additions by liberal annual applications of basic slag or other basic fertilizers.

The neutralization of the acidity of the soil is a chemical reaction and before it takes place the liming material must be dissolved. It is, therefore, apparent that fineness of the material, solubility, and intimate mixture with the soil are all important factors.

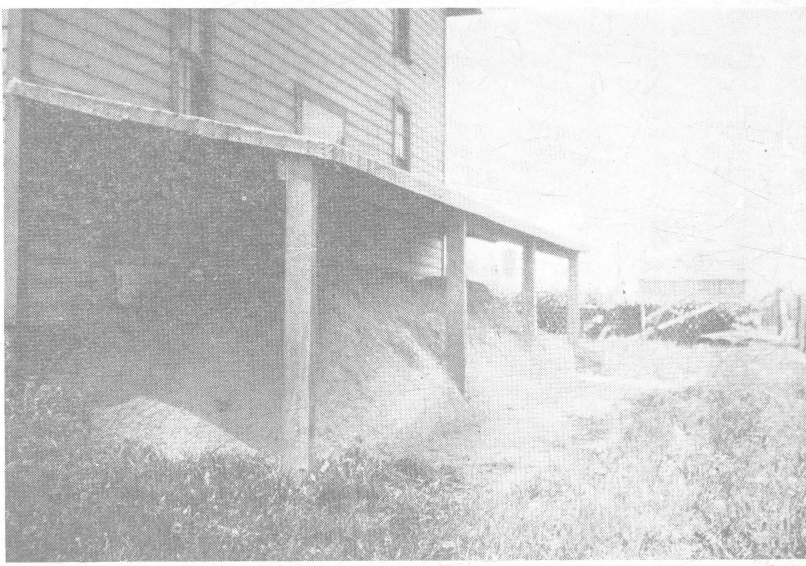

Fig. 3.—Protection from rain for limestone in storage saves much time and annoyance at spreading time.

## COMMON FORMS OF LIME FOR SOIL IN OHIO

*Limestone.*—Limestone is the source of practically all liming materials offered for sale in Ohio. If the raw stone is ground or crushed it is put on the market as screenings, meal, ground limestone, or pulverized limestone. The only difference in these products is the degree of fineness.

*Burned Limes.*—If the raw limestone is burned it is usually slaked and sold as hydrated lime, although there is a lesser amount sold as quicklime or caustic lime. The burning and hydrating processes reduce the stone to a fine powder, so the burned lime products are usually in a very finely divided state. The great difference in the burned lime products is in the total neutralizing power.

*Precipitated Carbonate.*—In certain industries lime which has been in solution is precipitated out in the form of the carbonate. Such a product is known as precipitated carbonate. The lime which collects in a teakettle in which hard water has been boiled is a similar product.

The particles are very fine and often have all the appearance of hydrated lime. Such products are often packed in paper bags and many farmers purchase them thinking they are getting hydrated lime. The total neutralizing power should be the guide used in determining the value of this material. As a general rule the amount of precipitated carbonate required would be the same as that of a very finely pulverized limestone. Their equivalent amounts would, therefore, be practically the same.

*Blast Furnace Slag.*—A by-product of the blast furnaces called "blast furnace slag" often has a total neutralizing power of 80 or more. This material has value as a source of lime. The water cooled slag sold in Ohio for agricultural purposes is a soft, porous material, but usually not finely ground. Tests in Ohio and Pennsylvania indicate that from 3 to 4 tons of such slag are required to be equivalent to 1 ton of agricultural ground limestone the first year after application. If results are not desired until the second year or later after application, about 2½ tons of slag are equivalent to 1 ton of agricultural ground limestone.

### TOTAL NEUTRALIZING POWER OF LIMESTONES

The active ingredients in raw limestone, precipitated lime, and marl are calcium and magnesium carbonate, while in the burned lime products they are transformed to calcium and magnesium oxides and hydroxides. Since these materials are in different forms in the different products it would be confusing to compare them on the basis of their actual analysis. For convenient comparison a common unit of measurement is necessary. Calcium carbonate or lime carbonate has been officially adopted for state control work, and is therefore quite generally used as the common unit of measurement of purity or concentration of lime in liming materials. In comparing different kinds of materials the calcium and magnesium oxides and hydroxides are all calculated in terms of calcium carbonate. The figure giving the sum of all the above materials in terms of calcium carbonate is known as "total neutralizing power in terms of calcium carbonate." It is usually abbreviated as "T.N.P." It makes possible a quick comparison of any two materials, whether the lime is in the calcium or magnesium carbonate, oxide, or hydrate form.

In this scale of values a pure calcium carbonate has a T.N.P. value of 100. Magnesium carbonate is 1.2 times as efficient in neutralizing acids as is calcium carbonate; a stone with some magnesium in it may thus have a total neutralizing power in terms of calcium carbonate of more than 100. This is frequently the case. Some dolomites sold in Ohio run as high as 108. If a limestone were composed of half impurities, such as sand or clay, its T.N.P. would be only 50. Stones of all degrees of purity in limestone are found in Ohio. Those sold commercially usually range between 95 and 106 in T.N.P.

Fig. 4.—On very acid soils the use of lime makes possible the growth of clover. Foreground, not limed; background, limed.

If 100 pounds of pure calcium carbonate is burned it is reduced to 56 pounds of quicklime, in which the calcium is found in the oxide form. The loss in weight has been brought about by the loss of carbon dioxide, which has no value in neutralizing soil acidity; hence the resulting product is more efficient, pound for pound, than the raw stone was before burning. Its increased efficiency is indicated by its total neutralizing power in terms of calcium carbonate. This is calculated as follows:

$100 \div 56 = 1.786$. The quicklime is therefore 1.786 times as effective as a soil neutralizer and its T.N.P. is 178.

If 56 pounds of quicklime is hydrated its weight is increased by combination with water to 74 pounds, but its total content of lime remains unchanged. Its weight (74 pounds) divided into 100 gives 1.35, which indicates its theoretical efficiency as compared with the raw stone or carbonate form; its T.N.P. is, then, 135.

Impurities in the raw stone are not lost by burning, but are carried over into the burned lime and hydrated limes which result.

### FINENESS OF PARTICLES DETERMINES RATE OF ACTION

Since it is necessary for any liming material to dissolve in the soil before it can neutralize acidity, the matter of fineness of the material applied becomes important. A given amount of limestone

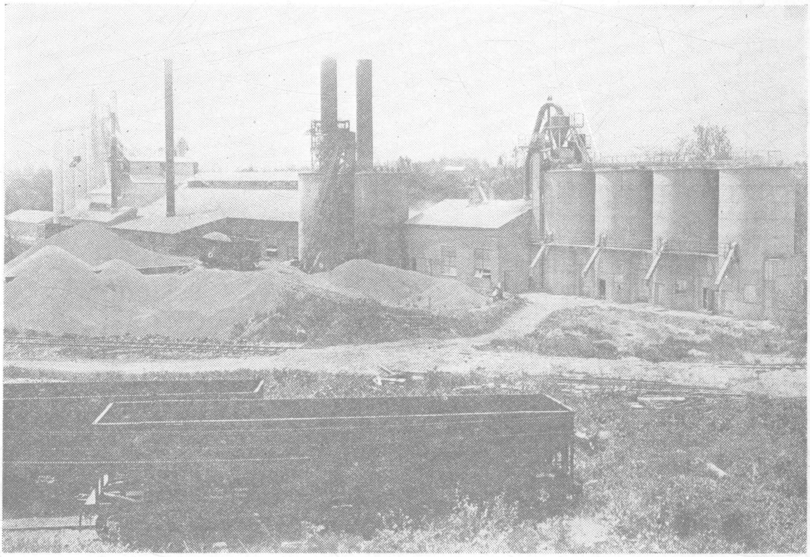

Fig. 5.—Large producing plant from which car-load shipments are made.

will dissolve much more rapidly if it is all reduced to a very fine powder than if reduced only to coarse granules. For purposes of comparison the percentages of different sized particles are determined by screening the product over sieves of various mesh sizes, such as 200-, 100-, 50-, and 10-mesh sieves. (A 100-mesh sieve is one which has 100 meshes per linear inch in both directions.) Particles passing through a 100-mesh sieve are known as 100-mesh material.

Fineness is particularly important with raw limestone products; those on the market vary widely in this respect. The only difference between screenings, meal, ground limestone, and pulverized limestone is that of fineness.

The Ohio Limestone Law recognizes three types of limestone based entirely on fineness. The following table gives the legal requirements for each type.

*Legal Fineness of Limestone Forms in Ohio*

| | Percent that will pass through a sieve of | | | | |
|---|---|---|---|---|---|
| | 100-mesh | 50-mesh | 10-mesh | 4-mesh | 3-mesh |
| Agricultural ground limestone.......... | 30 | 50 | 95 | .. | .. |
| Agricultural limestone meal............ | 20 | 30 | 80 | 100 | .. |
| Agricultural limestone screenings....... | .. | .. | .. | .. | 100 |

Many stones are being ground much finer than the legal requirements of agricultural ground limestone. Usually the most finely ground of these products are known commercially as pul-

Fig. 6.—Much labor is saved by spreading lime as it is hauled from the railroad.

verized limestone. Some are ground fine enough that 70 per cent or more will pass through a 100-mesh sieve.

Experimental evidence indicates that the value of a limestone cannot be indefinitely increased by increased fineness. Apparently when a certain degree of fineness is reached, increased speed of reaction in the soil produced by still finer grinding offers no practical advantage. Increased fineness increases the cost of production, and with increasing fineness a point is reached where the increased cost is greater than the value of the increased efficiency of the product. The optimum degree of fineness depends both upon cost per ton and the conditions under which the material is used.

The coarser particles have some value, as there is a constant dissolving action going on at their surfaces. Just how valuable they are is difficult to say, but in general their effect on the soil is relatively slow.

## EQUIVALENT AMOUNTS OF LIME TO APPLY

To correct a definite amount of acidity requires the solution of a definite amount of lime or lime carbonate. If the time required to bring about this change is neglected, then the relative amounts of two liming materials required to bring about an equal change will be inversely proportional to their total neutralizing powers. Thus, $1\frac{1}{2}$ tons of a product having a T.N.P. of 100 would be equiva-

Fig. 7.—A limestone application made four years previous gave this difference in sweet clover.

lent to 1 ton of a product with a T.N.P. of 150. Practically, however, the element of time is important. It has already been noted that the rapidity with which a ground limestone reacts with the soil increases with increased fineness. Hence, in arriving at the "equivalent amounts" of such materials both neutralizing power and fineness must be considered. Also, in stating "equivalent amounts," these must refer to some definite time or period after incorporation with the soil. For immediate effects coarse limestone has a lower efficiency than finely pulverized stone; where the effects are measured over a period of crop rotation, the difference is less. If time were allowed for complete solution of all materials, then presumably all would show efficiencies in proportion to their total neutralizing powers.

The following table of "equivalent amounts" is based on field and laboratory studies of the Ohio Agricultural Experiment Station. Both fineness and total neutralizing power have been considered in arriving at the "equivalent amount" for any product. While exactness is not claimed for these figures, it is believed that they represent the relative values of the different materials as accurately as present information will permit their estimation.

*Equivalent Amounts of Liming Materials*

| Kind of material | Total neutralizing power | Material passing through 100-mesh sieve | If applied at least the season before legume seeding | If applied at time of legume seeding |
|---|---|---|---|---|
| | | % | *lbs.* | *lbs.* |
| Pulverized limestone............. | 100 | 65–70 | 2000 | 2500 |
| Agricultural ground limestone.... | 100 | 45–50 | 2200 | 3000 |
| Agricultural limestone meal (fine) | 100 | 30–40 | 2450 | 3350 |
| Agricult'l limestone meal (coarse) | 100 | 20–30 | 2850 | 4350 |
| Hydrated lime.................. | 135 | 100 | 1380 | 1600 |
| Hydrated lime.................. | 170 | 100 | 1090 | 1260 |

Any of these materials will produce approximately the same crop increases when used in the amounts given.

In deciding which of the materials is the most economical one to purchase it is important to include freight and the cost of hauling from the railroad station to the field in the total cost. On short hauls the coarser materials needed in larger amounts have the advantage, but when long hauls are necessary the more concentrated and finely pulverized materials enjoy an advantage because of the saving in tonnage. (Twenty cents a ton mile is considered an average figure for cost of trucking lime. Wagon haul expense is usually less than trucking on short distances.)

The increased amounts of the coarser products required when action in the soil is wanted the season of application is important.

## PHYSICAL PROPERTIES

The hardness of limestone, its weight, its porosity, or its color apparently have no relationship to its solubility, and therefore should not form the basis of comparison between materials. *Fineness is the one physical property of importance.*

## CHEMICAL COMPOSITION OF LIMESTONES COMPARED

Experiments in Ohio show very good results from the use of finely ground dolomitic limestones (see page 23.) As stated, of two stones equally free from foreign material the one containing the higher content of magnesium carbonate will have the higher neutralizing power. This difference in the T.N.P. between high calcium stones and dolomites usually amounts to about 8 points.

Dolomitic limestones dissolve more slowly than high calcium limestones of equal fineness. This difference is of no practical consequence with finely pulverized stones, and is also negligible for the hydrate and oxide forms. With coarsely ground products it becomes a matter of some importance.

In general, solubility studies indicate that high magnesium limestones should carry about 10 per cent more 100-mesh material than high calcium limestones in order that the two forms may have equal value. In arriving at this relationship, allowance is made

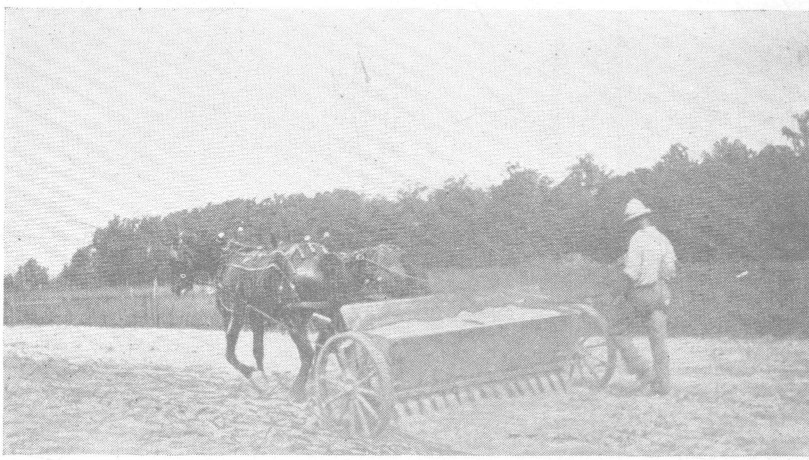

Fig. 8.—A good job of spreading lime can best be accomplished by the use of a machine especially designed for that purpose.

for a difference of 8 points in T.N.P. in favor of the dolomite. If magnesium were needed in the soil as a plant food the dolomitic stones would be preferred, but there is no evidence of any such need in Ohio soils.

### SOIL TESTS FOR LIME REQUIREMENT

Several chemical tests for determining the amount of acidity in the soil have been devised. Most of them require considerable apparatus and equipment and so are not adapted to field use.

*The Litmus Paper Test.*—Perhaps the oldest test is that made by using litmus paper. If not carefully carried out this test is likely to be misleading. At best it gives little idea of the amount of lime needed. It is not recommended for general use.

*The Thiocyanate Test.*—The thiocyanate test, originated in England by Comber, is a reliable test if the directions are followed closely. An accurately standardized 4 per cent solution of potassium thiocyanate in alcohol, a test tube, and a color chart comprise all the necessary equipment. About equal volumes of soil and thiocyanate are thoroughly mixed by shaking together in a small test tube. The tube is then set aside for about five minutes until the soil again settles and some of the liquid comes to the top free from murkiness. The test is based on the amount of red coloration occurring in this supernatent liquid. By reference to a color chart, the lime requirements can be estimated.

Because of its simplicity the test lends itself well to field work. It is not an accurate test for soils near the neutral point, but is useful for soils of moderate to high acidity. Mucks, peats, and sandy soils cannot be accurately tested by this method.

*p*H *Value.*—Most of the more recently devised tests measure the *p*H value or hydrogen ion concentration of the soil. The *p*H is a measure of the intensity of the acidity. It may be measured either colorimetrically or electrometrically.

In the colorimetric tests the *p*H value is determined by mixing small amounts of soil with solutions of organic dyes which give different shades of colors at different *p*H values. The accuracy depends on one's ability to match the color developed with standard color charts. Because of the simple equipment required these tests lend themselves well to field use.

For the electrometric measurement of *p*H values considerable expensive equipment is required. This method, therefore, cannot be recommended for general use. It is, however, considered the more accurate of the two methods.

In the numerical scale of *p*H values, 7 represents neutrality. Soils which are acid have a *p*H value below 7 and those which are alkaline have a *p*H value above 7. Soils are seldom found in Ohio which go beyond the limits of 4.25 to 8.00.

*pH Value Below Which Growth of the Following Crops Should Not Be Attempted*

| *p*H Value | Crops | *p*H Value | Crops | *p*H Value | Crops |
|---|---|---|---|---|---|
| 6.50 | Alfalfa | 5.50 | Red Clover | 5.00 | Alsike Clover |
| 6.50 | Sweet Clover | 5.50 | Corn | 5.00 | Soybeans |
| | | 5.50 | Wheat | 5.00 | Cow Peas |
| 6.00 | Cabbage | 5.50 | Cantaloupes | 5.00 | Potatoes |
| 6.00 | Cauliflower | 5.50 | Timothy | 5.00 | Red Top |
| 6.00 | Lettuce | 5.50 | Canada field peas | 5.00 | Oats |
| 6.00 | Spinach | 5.50 | Ky. bluegrass | | |
| 6.00 | Barley | | | 4.5 | Strawberries |
| 6.00 | Sugar Beets | 5.25 | Mammoth clover | 4.5 | Watermelons |
| | | 5.25 | Canada bluegrass | 4.5 | Buckwheat |
| | | 5.25 | Tobacco | 4.5 | Rye |

## HOW MUCH LIME FOR A GIVEN *p*H VALUE?

Crops differ in their response to lime because they differ in their ability to tolerate acidity in the soil. Soils also differ in their response to lime. In the lighter silt loams acidity represented by a given *p*H value is neutralized with less lime than in the heavy clay soils. Some dark colored soils, such as are often found in northwestern Ohio, will grow clover at a lower *p*H than the light colored soils. Because of these variations it is impossible to say that a soil with a given *p*H value will need a definite amount of lime for any particular crop. Nevertheless, generalizations may be made. An idea of the amount of lime needed for light or heavy soils for different crops may be obtained from the following table.

*Lime Requirements for Varying Soils and Crops*

| | Approximate lime requirement* | | |
|---|---|---|---|
| | *p*H value of soil | Silt loams (light soils) lbs. | Heavy clay (heavy soils) lbs. |
| HIGH LIME REQUIREMENT CROPS: | | | |
| Alfalfa, celery, radish, sweet clover, | Above 6.5 | ........ | 0–2000** |
| sugar beets, barley, cabbage, | 6.5–6.0 | 1000–2000 | 2500–4000 |
| spinach, peas, lettuce, onions, | 6.0–5.5 | 2000–4000 | 4500–6000 |
| carrot, cauliflower, asparagus. | 5.5–5.0 | 5000–6000 | 6000–8000 |
| | 5.0 and below | 6000–8000 | 10,000 or more |
| MEDIUM LIME REQUIREMENT CROPS: | | | |
| Red clover, mammoth clover, white | Above 6.5 | .. | .. |
| clover, corn, Kentucky bluegrass, | 6.5–6.0 | .. | 500–1500 |
| permanent pastures, cantaloupes, | 6.0–5.5 | 500–1500 | 2000–3000 |
| tobacco, timothy. | 5.5–5.0 | 2000–3500 | 4000–5000 |
| | 5.0 and below | 4000–5000 | 6000–8000 |
| LOW LIME REQUIREMENT CROPS: | | | |
| Alsike clover, oats, wheat, soybeans, | Above 6.5 | .. | .. |
| cow peas, Japan clover, red top, | 6.5–6.0 | .. | .. |
| Canada bluegrass, rye, beans, buck- | 6.0–5.5 | 500–1000 | 1000–2000 |
| wheat, strawberry, watermelon, | 5.5–5.0 | 1000–2000 | 2000–4000 |
| rhubarb. | Below 5.0 | 2500–4000 | 4500–6000 |

* In terms of agricultural ground limestone.
** The larger amounts suggested in this table are applicable only in exceptional cases.

*Increase the Amount if Applying at Legume Seeding Time.*—When soil tests are used as a basis for determining the lime requirement of a soil, the recommendations are usually given in terms of agricultural ground limestone to be applied at least the season before legume seeding. If for some reason the application is made at legume seeding time the amount of material used should be increased 25 per cent.

## WHEN TO APPLY LIME

In a four-year rotation of corn, oats, wheat, clover at Wooster in which the soil was plowed twice (for corn and wheat) applications of ground limestone on sod to be plowed for corn, on plowed ground for corn, and on plowed ground for wheat have all given about the same crop increases. In the same rotation applications on young clover after wheat harvest have not given as large crop increases.

No similar tests have been run in a three-year rotation in which the soil is plowed but once. There is evidence for the belief that in such rotations lime applications should be made on top of plowed ground and well worked into the soil. In such a rotation the corn or wheat crop should get the lime.

Fig. 9.—In a four-year rotation where land is plowed for both corn and wheat, good stands of clover may be secured by applying lime on sod before plowing for corn.

Recent experiments at Wooster, although not yet productive of conclusive results, give some interesting indications regarding applications of lime. Where liming has been delayed until the time of seeding clover in wheat, better stands of clover have been obtained by drilling the lime and clover seed together, than where an equal amount of lime was broadcast either before seeding the clover in the spring or before wheat seeding in the fall.

Comparatively small applications of fine limestone or hydrated lime drilled with the clover seed have given surprisingly good results on a soil of moderate acidity. This should be of particular interest to the farmer whose soil needs considerable lime and who has a long haul from the railroad. For this situation it is suggested that the application to wheat be reduced to around one-half of the lime requirement of the soil and that a subsequent application of 500 pounds per acre of fine limestone or its equivalent of hydrated lime be drilled with the clover seed in the spring.

### HOW MUCH LIME TO APPLY

Extra large applications of lime have not been found profitable in Ohio. On the Ohio Experiment Station farm at Wooster on a silt loam soil with a lime requirement between 1½ and 2 tons of ground limestone per acre, different amounts of ground limestone were applied to corn in a corn, oats, wheat, clover rotation. The results for twelve years are given below by four-year periods:

*Results of Increasing Applications of Ground Limestone**

| Period | Limestone application, tons | Total value of crop increase | Cost of lime | Balance |
|---|---|---|---|---|
| First 4 years: | 2 | $16.47 | $10 | $ 6.47 |
| | 4 | 23.13 | 20 | 3.13 |
| | 8 | 26.98 | 40 | —13.02 |
| Second 4 years: | 2 | 24.07 | 10 | 14.07 |
| | 4 | 27.82 | 20 | 7.82 |
| | 8 | 31.35 | 40 | —8.65 |
| Third 4 years: | 2 | 30.54 | 10 | 20.54 |
| | 4 | 43.12 | 20 | 23.13 |
| | 8 | 22.98 | 40 | —17.02 |

* 44th Annual Report of the Ohio Agricultural Experiment Station.

It is evident that the most profitable application has been the one nearest the actual lime requirement. In another test on similar soil, increasing amounts of lime were applied to corn in a corn, oats, clover rotation. As a thirteen-year average, lime equivalent to 1 ton of ground limestone increased the yield of red clover 1103 pounds. Where the application of lime was doubled, only 319 pounds of clover was added to this increase.

### DOES LIME DESTROY ORGANIC MATTER?

It has been well established that liming hastens the decay of organic matter in the soil. Nevertheless, where lime has been applied in rotative cropping, analyses of the soil have frequently shown that the content of organic matter has not been reduced. The principal source of organic matter in the soil is the roots and stubble of the crops grown. Since limed soils produce larger crops, greater amounts of organic matter are each year returned to the soil. This additional supply of crop residues explains why it is that limed soils are able to keep pace with the increased decay of organic matter caused by liming. The value of organic matter in the soil as a source of plant nutrients is obtained only as this material decays. Apparently, lime merely causes a quicker "turn-over" of the organic matter in the soil.

Destruction of organic matter should not be a deterrent to the use of lime. Neither is there sufficient difference in action on organic matter between hydrated lime and ground limestone to be a factor in choosing between the two materials.

Fig. 10.—Liming increased the yield of hay from 1424 pounds (left) to 3584 pounds per acre.

## WILL LIME PAY AS WELL OR BETTER THAN FERTILIZER?

Many times the farmer feels that he cannot afford to purchase both lime and fertilizer, and must decide which one will give him the greater return for the money he has to spend. The Ohio Experiment Station has collected data over a period of years which answers this question for soils similar to those at Wooster. The results are probably applicable to other acid soils in Ohio.

In Bulletin 382 the findings of the Station are summarized as follows: "In a five-year rotation of corn, oats, wheat, clover, and timothy the average value of the crops less the cost of lime has been $79.16 per acre on plots which received lime but no fertilizer. On the fertilized but unlimed plots the value of the crops less the cost of fertilizer has been $46.57. Stating the case differently, limestone alone has increased the crops 183 per cent, while fertilizer alone has increased the crops 145 per cent. The percentage increases in yield from fertilizer have been greatest on wheat crops and least on hay."

In a four-year rotation at Wooster the following yields were obtained from separate lime and fertilizer applications.

| Treatment per acre | 13-year average yields | | | |
|---|---|---|---|---|
| | Corn bu. | Oats bu. | Wheat bu. | Clover lbs. |
| 2 tons ground limestone on corn.... | 52.39 | 54.58 | 24.92 | 3571 |
| 8 tons manure on corn, 480 lbs. 0-16-0 on wheat........ | 53.39 | 53.67 | 26.24 | 3024 |

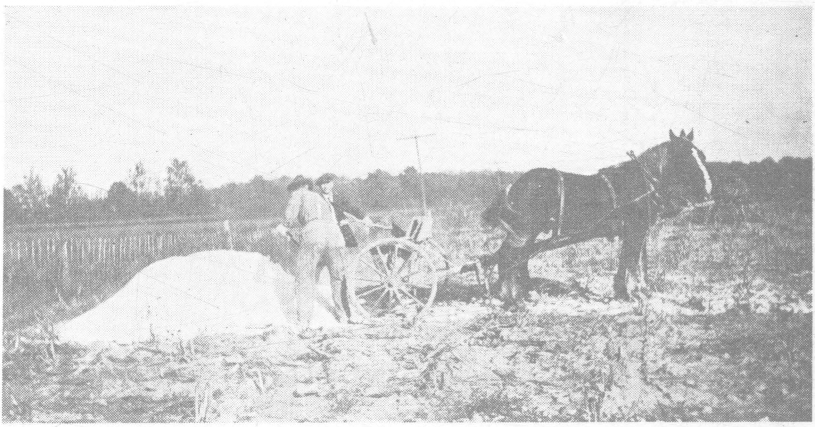

Fig. 11.—Liming corn ground before disking for wheat gives opportunity to mix lime well into the top soil.

While the difference between the two treatments is small, slightly larger yields were obtained with the limestone.

The general conclusion seems justified that where soil acidity limits crop production and where profits over the whole rotation or longer are considered, lime alone is apt to be a better investment than fertilizer alone. For a renter who is interested only in the immediate crop the fertilizer may be the best investment. It should be kept in mind, however, that the largest crop increases are obtained only when both lime and fertilizer are used on acid soils. Fertilizers give largest returns on limed land. It is always preferable that lime be used as a supplement to liberal applications of manures and fertilizers, and not as a substitute for either or both.

## WHERE NOT TO USE LIME

It is hazardous to mix lime and manure in storage because of the danger of liberating nitrogen in the form of ammonia if the manure should become too dry.

It is usually not advisable to mix lime and commercial fertilizers outside of the soil. With some materials like sulfate of ammonia there results an actual loss of nitrogen. With superphosphate there is a tendency for the lime to cause a reversion of the readily available water soluble phosphoric acid to the more slowly available "citrate soluble" form. If the contact between lime and fertilizer takes place in the soil no ill-effects result.

Applying lime to soils before planting to potatoes is seldom advisable, since the organism which causes potato scab thrives better in a limed soil than in a soil of moderate acidity.

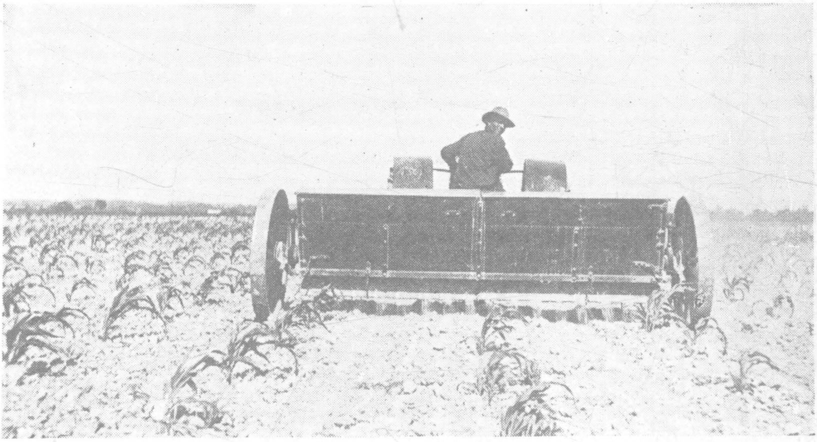

Fig. 12.—Many farmers are finding it satisfactory to apply lime just after corn planting.

## WHAT LIME SHOULD NOT BE EXPECTED TO DO

Lime is not a "cure-all." It does not take the place of fertilizers in good farm practice, since it contains no nitrogen, phosphorus, or potash.

Lime will not take the place of good rotations or cultivation. As a matter of fact, if its use is to be most profitable proper cultivation and good rotations must be practiced.

Liming will not take place of drainage. Lime affects only the upper soil. Impervious layers of hardpan must be broken up by some other means than liming. Many years of liming have failed to affect more than the plow layer.

Local deposits of limestone frequently have a high neutralizing power and are satisfactory for agricultural purposes. In communities not well served by railroads it is often more economical to use this stone than to attempt to ship or truck in the commercial products. Before spending any time or money on local limestone deposits the total neutralizing power should be determined, as it is unprofitable to work low testing stone. In developing a local stone deposit one has the choice of grinding or burning.

*Home Grinding.*—The grinding of limestone locally is usually done with a portable crusher. The expense of producing ground limestone by this method depends on different factors, chief of which are the ease with which the stone may be gotten out and the cost of power and labor.

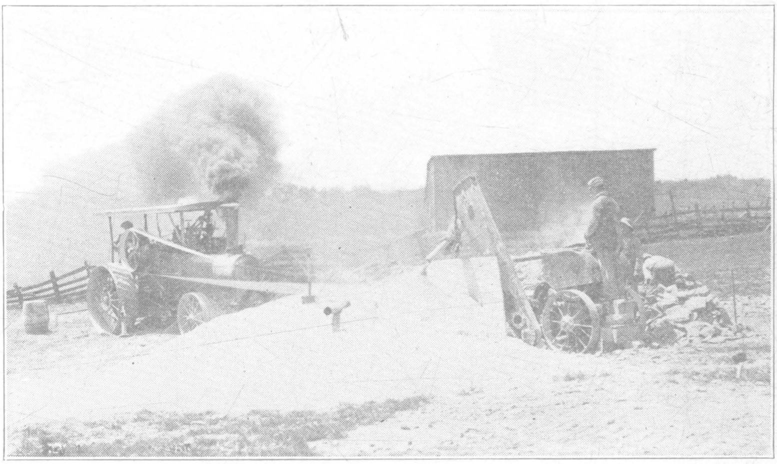

Fig. 13.—Taking advantage of local resources.

Because of a lack of sufficient power the limestone ground by portable crushers in Ohio has not, as a rule, been very finely pulverized. Screen tests on a good many samples indicate that the product is usually not much finer than the commercial product mentioned in the table on page 11 as coarse limestone meal. The price of commercial limestone meal delivered to the farm as compared with its cost as produced by home grinding will ordinarily tell whether or not it is economical to grind at home. Under most conditions home grinding is a more economical method of handling local limestone than is burning.

*Burning Lime in a Stack.*—A satisfactory liming material may be produced by burning lime in a stack. Extremely cheap fuel and

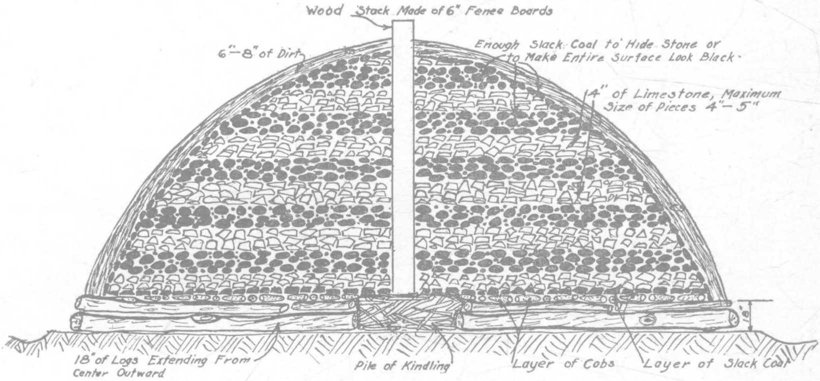


Fig. 14.—Diagram showing construction of hemispherical stack for burning lime.

labor are necessary to produce lime economically by this method. The labor expense is usually the greater.

The accompanying diagram illustrates how a lime stack may be built. It may be built either in the shape shown or with the top more nearly flat. Pieces of stone 8 inches in diameter may be left whole if they are placed near the center of the stack where the temperature will be highest. Toward the outer edge smaller pieces should be used. Usually about 3 weeks are required for complete burning and cooling of the stack.

When the stack is completed it is fired by pouring kerosene down the wooden flue in the center and igniting it. Fires should also be started at from four to six points around the outside of the stack. As the pile burns, "cave-ins" will occur daily; these should

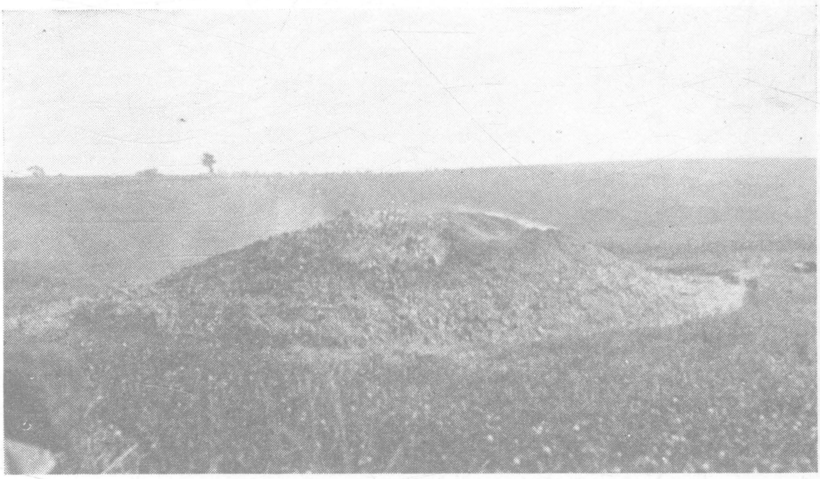

Fig. 15.—A burning limestack must be kept covered with dirt to prevent loss of heat.

be covered with soil as soon as discovered in order to prevent the escape of heat (see Fig. 15).

When the stack has cooled the lime may be hauled to the field. Much discomfort may be avoided if the lime is thrown into small piles to slake. It is well to cover each pile with a few shovelfuls of dirt to absorb dust and make spreading more agreeable. After standing two or three weeks it will be found to have become finely powdered and will spread easily.

One bushel of lime to a pile, with the piles 40 feet apart each way, will make an application of a ton per acre.

The lime may be slaked in the stack by adding water at different places. In this case it will be impossible to separate the lime from the soil with which the stack was covered.

Since so little lime is burned in Ohio more detailed information regarding materials and size of stack is omitted. Such information will be furnished on request.

## FERTILIZER MATERIALS REPUTED TO HAVE SOME NEUTRALIZING POWER

*Bone Meal.*—Bone meal is a carrier of phosphate in combination with calcium. It usually contains about 7 per cent of carbonate of lime. The amount of free lime available for neutralizing acids is thus small. While the continued use of bone meal adds some lime, its effect on soil acidity is not as large as that of basic slag.

*Basic Slag.*—Basic slag is a by-product of the iron industry and is usually purchased for its phosphate content. It carries considerable lime, the total neutralizing power in terms of calcium carbonate ranging from 15 to 50.

*Superphosphate.*—Superphosphate is used for its phosphate content and contains no free lime. It has been frequently shown that the continued use of superphosphate produces no significant change in the acidity of the soil.

*Ashes.*—Hardwood ashes contain both calcium and magnesium oxides. In terms of calcium carbonate the total amount is sometimes as high as 70 per cent. They are quite valuable for neutralizing soil acidity.

*Gypsum.*—Gypsum, also known as land plaster, is a form of calcium sulfate. The lime combined as sulfate is not active in neutralizing soil acidity. It has no value for correcting soil acidity. It is contained in fairly large quantities in ordinary superphosphate.

*Cyanamid.*—Cyanamid is a synthetic fertilizer used mainly for its nitrogen. It contains both calcium hydroxide and carbonate. In terms of calcium carbonate it has a total neutralizing power of about 100. It is effective in neutralizing soil acidity, but is ordinarily used in too small amounts to give practical results in correcting soil acidity.

*Manure.*—Manure contains some calcium in combination with organic material. When applied to the soil, manure helps to supply the growing crop with calcium, but is not effective in neutralizing soil acidity. The continued use of manure has not been found to produce any significant change in the acidity of the soil. The beneficial effect of manure on clover is usually due to the plant food supplied.

*Floats (Raw Rock Phosphate).*—Pulverized rock phosphate is used in the manufacture of superphosphate and also applied directly to the land as a fertilizer. Its phosphorus is in combination with calcium, and it has therefore been suggested that it should tend to lower the acidity of soil. On the Experiment Station farm at Wooster the use of 1000 pounds of floats every 3 years over a period of 24 years has produced no significant reduction in the acidity of the soil. Apparently, the value of floats is based primarily on its phosphorus content.

## TERMS USED IN LIMING

*Air Slaked Lime.*—Burned or caustic lime when exposed to the air reabsorbs the water and carbon dioxide gas which was driven off from it during the burning. This process is called slaking and the product is called air slaked lime. If the action is complete the lime is again in the carbonate form, the same as before burning.

*Caustic Lime.*—The product resulting from burning limestone is known as caustic lime. After slaking it is no longer caustic (see also Quicklime).

*Calcium Carbonate.*—Calcium carbonate is the name of the chemical compound in which lime occurs in limestone, marl, chalk, oyster shells, etc. It is a combination of lime and carbonic acid gas.

*Calcium Hydroxide.*—See Hydrated Lime.

*Calcium Oxide.*—See Quicklime.

*Chalk.*—Deposits of impure white or grayish calcium carbonate which have not solidified to any great extent are sometimes known as chalk. It has about the same chemical properties as limestone. It is more commonly called marl.

*Dolomite.*—Limestones containing considerable magnesium carbonate are known as dolomite or dolomitic stones (see pages 7 and 11).

*Ground Limestone.*—Ground limestone is the term commonly applied to the raw limestone which has been mechanically ground or pulverized.

*High Calcium Stone.*—A limestone containing a high percentage of calcium and a low percentage of magnesium is known as a high calcium stone.

*High Magnesium Stone.*—A dolomitic limestone containing a high percentage of magnesium and relatively less calcium is known as a high magnesium stone.

*Hydrated Lime.*—Burned or quicklime to which water has been added (water slaked) is known as hydrated lime. The calcium is contained in it in the hydroxide form.

*Lime Carbonate or Carbonate of Lime.*—Lime carbonate refers to lime as it occurs in nature as limestone. It ordinarily includes both the calcium and magnesium carbonates present. Precipitated lime is also a lime carbonate (see Calcium and Magnesium Carbonate).

*Lime Oxide.*—See Quicklime.

*Lime Requirement.*—Certain chemical tests are applied to soils which measure the amount of acidity present. The amount of lime required to neutralize enough of this to permit the growth of certain crops is known as "lime requirement." In Ohio this is given in terms of agricultural ground limestone unless some other kind of lime is specifically stated.

*Limestone Meal.*—Raw limestone ground a little too coarse to be classed as ground limestone is known in Ohio as meal (see Table, page 9).

*Limestone Screenings.*—Raw limestone so coarsely ground that it cannot be classed as limestone meal is called screenings (see Table, page 9).

*Lump Lime.*—See Quicklime.

*Magnesium Carbonate.*—Magnesium carbonate is that form of magnesium in which it occurs in nature as in limestone, marl, etc. It is a compound of magnesium oxide and carbonic acid gas (see Lime Carbonate).

*Marl.*—Impure deposits of carbonate of lime which are water laid in beds in a more or less friable condition are called marl. It is sometimes solidified enough to require grinding before being used on soil. The calcium and magnesium contained in marl is in the carbonate form the same as in ordinary limestone.

*Marble.*—Marble is a very hard, compact form of limestone capable of being polished. The lime contained in it is in the carbonate form. It is too valuable for agricultural purposes, but the dust or waste may be used.

*Oxide of Lime.*—See Quicklime.

*pH Value.*—(hydrogen ion concentration). The *p*H value of a soil is the measure of the intensity of its acidity or alkalinity. In the scale of *p*H values 7.0 represents neutrality. As the acidity increases the *p*H value becomes less.

*Precipitated Lime.*—A precipitated lime is one that has once been dissolved in water and then brought back to the powder form by carbonation or evaporation. The lime deposit in a teakettle in which hard water has been boiled is precipitated lime. Such lime is in the carbonate form, the same as in limestone. Due to the process of formation, it is usually finely divided.

*Pulverized Limestone.*—According to the classifications given in the Ohio limestone law, pulverized limestone may mean any kind of ground limestone. As applied to commercial products in recent years it refers to limestone which has been made finer than ordinary agricultural ground limestone.

*Quicklime.*—Quicklime is burned lime before slaking. The calcium and magnesium in it are in the oxide form. It is commercially known also as burned lime, lump lime, caustic lime, calcium oxide, lime oxide, stone lime, or builders' lime.

*Screen Test.*—The screen test of a lime refers to the determination of the percentages by weight of the material which will pass through screens of different mesh sizes.

*Slaked Lime.*—After burning, lime reabsorbs the water and carbon dioxide gas which was driven off during the burning. When part or all of these materials have been reabsorbed the lime is said to be slaked. It may be water slaked or air slaked.

*Slag.*—Slag is a by-product of blast furnace operations resulting from the use of limestone flux in purifying crude iron ore (see page 6). It is commonly called blast furnace slag or agricultural slag.

*Total Neutralizing Power in Terms of Calcium Carbonate.*—(T.N.P.). That figure which gives the value in terms of calcium carbonate of all the material in lime capable of neutralizing acidity is known as the total neutralizing power in terms of calcium carbonate. It makes possible a quick comparison of two materials either of the same or of different chemical composition. It is often abbreviated and written T. N. P. (see page 6).

*Waste Lime.*—Oftentimes there are by-products of certain manufacturing plants which contain lime oxide or carbonate of lime. These are known as waste lime. Such products come from water softening processes, gas works, beet sugar mills, tanneries, paper mills, spent calcium carbide, the iron industry, etc. These may contain compounds which are injurious to crops. Before using any such product its total neutralizing power and freedom from injurious compounds should be determined.

THE OHIO STATE UNIVERSITY, COOPERATING WITH THE UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL EXTENSION SERVICE, H. C. RAMSOWER, Director, Columbus
FREE — Cooperative Agricultural Extension Work — Acts of May 8 and June 30, 1914.